Flaw Tolerance in Pipeline Girth Welds subjected to Axial Straining and Internal Pressure – Strain ECA

PUBLISHABLE SUMMARY

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Background

Oil and gas pipelines frequently experience strains greater than yield during pipelay and in service. It is therefore critically important to understand the flaw tolerance associated with girth welds in pipes during plastic straining. A number of factors, in addition to axial strain, will affect flaw tolerance. For example, the driving force on a flaw is known to be substantially greater when the pipeline is under internal pressure if large axial strains are applied. Material resistance, however, is thought to be unchanged by internal pressure.

Current assessment procedures based on codified methods such as BS 7910 experience difficulties in dealing with these conditions since they are essentially stress based. Indeed, where they have to be used, there is uncertainty in their validity and safety. Consequently, there is a need to develop new, robust and validated procedures that can be used with confidence by industry. This Joint Industry Project quantified the main factors that affect flaw tolerance at post yield strain levels so that a rigorous, industry agreed method of flaw assessment could be written and the risk of failure minimized. The method was validated through full scale pipe tests which involved plastic straining with internal pressure.

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Objective

Develop a robust and validated strain-based assessment procedure which quantifies the most important variables that influence flaw tolerance of girth welds in pipelines subject to axial straining with and without internal pressure.

Project Outcome

- The results from full-scale pipe tests conducted with internal pressure plus axial plastic strain, identified a lower strain capacity than pipe subjected to axial straining alone. This is consistent with previous tests conducted on plain and welded pipe and also predictions made from finite element analyses.
- Four pipe test strain capacities were conservatively predicted using small strain FEA. Two tests with notches in the weld metal had lower strain capacities than predicted by FEA.
- A proposed correction to the existing stress-based FAD in BS 7910 (for Levels 2b and 3c) making it suitable for strain-based assessments, has been used to analyse one of the pipe tests. The comparison of the predicted CTOD driving force with experimental data showed that the proposed correction has merit.

Benefits

An industry agreed strain-based flaw assessment procedure which will be available within the framework of a codified assessment.

Participants

The Sponsor Group comprised the following companies:

- Saipem
- Subsea 7
- Acergy (now part of Subsea7)
- Petrobras
- ExxonMobil

Scope of Work

- Six tests were undertaken. Four had circumferential cracks in weld metal and two had circumferential cracks in the base metal. Notches were introduced by electro-discharge machining (EDM) into the outside of the pipe. Three pipes were plastically loaded in tension until failure. Three tests were internally pressurised to 620barg with water to produce a hoop stress of approximately 87% of parent pipe yield strength (RP0.5% = 523MPa). Subsequently, these pipes were axially loaded in tension until either through pipe wall tearing (a leak in the case of the internally pressurised pipes) occurred from one of the notches or pipe failure. All pipes were instrumented to record pressure, applied force, local strain, overall strain, and crack mouth opening. The results were analysed to provide the relation between stress and strain, local strain and remote strain, CTOD and strain. In addition, the CTOD values predicted from finite element analyses with or without correction for ductile crack extension were compared with the experimental data.

- Unloading compliance was used to estimate crack extension and the CTOD resistance curve (R-curve) generated at each of the pipe/weld notches. Those results were compared with R-curves determined using SENT specimens. Finally, a limited comparison was made between J-integral (derived from CTOD) in the pipe and J derived from a conventional (BS 7910 Level 2b) stress-based FAD and a new strain-based FAD.
- A seventh full-scale pipe test was conducted as a supplementary project supported by three of the original sponsors. This test was similar to the sixth test except that the internal pressure was reduced to represent a typical operating condition and to maximise the effects of bi-axiality.

Project Budget

The main project had a budget of £500,000. It was funded by 5 Sponsors each making a contribution of £100,000. The supplementary project had a budget of £67,500, funded by 3 of the original sponsors. The fee for additional companies buying-back into the complete project results is £122,500.

Further Information

For further information on how a Joint Industry Project (JIP) runs please visit:

http://www.twi-global.com/services/research-and-consultancy/joint-industry-projects/

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